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AN ANALYSIS OF INTERURBAN AIR TRAVEL IN CANADA

by

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The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies for acceptance, a thesis entitled An Analysis of Interurban Air Travel In Canada, submitted by Brian Gustafson in partial fulfilment of the requirements for the degree of Master of Business Administration.

ABSTRACT

It has been hypothesized that air travel between two cities, with populations Pa and Pb, that are separated by a distance D, will be directly proportionate to the product Pa X Pb, and inversely proportionate to the distance D, raised to some exponent. This study attempts to verify the hypothesis with respect to the Canadian air travel market.

More specifically this study examines the influence of population, distance, income, and total airport departures on air travel between the ten largest traffic generating cities in Canada. The study examines the theoretical basis for the selection of the explanatory variables and reviews several empirical studies which develop and employ the above mentioned hypothesis. The study uses simple regression to determine the influence of each of the explanatory variables on air travel.

The study concludes that the hypothesis is not confirmed for the Canadian air travel market. In fact, the hypothesis is rejected for short and medium distance routes.

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TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

The General Problem

Airline managements require forecasts of future traffic growth for equipment acquisition, facility development, employee recruitment and budgeting. More immediate decisions are often required on whether additional expense and effort should be spent to build up traffic on existing routes, or to establish new routes. Standards are required to evaluate and compare advertising, promotion and service patterns - which cities, for example, might be more receptive to stimulation of traffic by advertising and other sales effort. A means of evaluating the entire route structure, both in terms of which routes are above and below average in traffic generating potential, and in terms of evaluating the rate of change of traffic on individual routes would assist management in determining which routes are, and which are not, being properly developed. In these and other questions of route development, management would be aided by a consistent and systematic method of analysis. One such method is the PP/D hypothesis.

Purpose

The purpose of the study is to determine whether air travel between major Canadian cities can be explained and predicted by two factors, population and distance, the relationship between which is hypothesized to be of the form PP/D. The PP/D hypothesis states that in general air travel between two centres of population is directly related to some measure of population of the two centres and inversely to some measure of the distance between them. Mathematically the PP/D hypothesis is expressed as follows:

$$Tij = f(Pi\ Pj\ /\ Dij^{x})$$

where Tij = Amount of air travel between centre i and centre j, expressed as the number of passengers.

Pi = some measure of population of centre i

Dij = distance between centre i and j

x,f = some functional relationship depending on the data.

Various measures of population are tested together with a common distance factor, the exponent of which is varied to yield the most appropriate results.

The procedure will involve relating population (or various substitutes) and distance (to some exponent) expressed in the PP/D form, to observed air travel over 45 routes. Regression analysis will be used to develop the relationship.

Finally it is the purpose of this study to determine whether the relationship between population, distance and air travel is stable over time, and hence can be used for forecasting. To this end, results of regressions using 1961 data will be compared to regressions using 1966 data.

Statement of Hypothesis

It is the hypothesis of this study that air travel demand between Canadian cities is largely a function of two factors, population and distance. Specifically, it is hypothesized that air travel between any two cities is directly related to the product of the population of the two cities and inversely related to the distance between them. It is further hypothesized that a linear relationship exists between observed air travel and calculated values of the PP/D formula. It is finally hypothesized that the relationship is constant over a variety of cities and over a period of years.

Outline of the Study

The object of this study is to relate factors causing air travel to observed air travel. The first step therefore is to examine the factors that characterise and cause air travel. This is done in Chapter 2.

The development of the PP/D hypothesis as it applies to air travel is covered in Chapter 3. Various applications of the PP/D hypothesis to air traffic sit-

uations are summarized.

Various substitutes for the basic population data are to be tested and compared to the results using population. The selection of these various substitutes is explained in Chapter 4. The sources of the data to be used in the study are indicated. The statistical analysis to be undertaken is specified in the chapter.

The actual testing of the hypothesis is reported on in Chapter 5. Population and various substitutes are regressed against observed air traffic. The results of these regressions are presented in Chapter 5, together with an analysis of the results.

A brief summary starts off Chapter 6. The limitations of the study are outlined and the conclusions are drawn in this final chapter.

CHAPTER II

FEATURES OF THE AIR TRAVEL MARKET

Introduction

The main obstacle to market research in air transport is the practical difficulty of obtaining applicable information. Whenever possible, information on the Canadian market is used. In some cases it has been necessary to refer to information pertaining to the United States and assume that the findings apply to the Canadian market. In other cases it has been necessary to refer to general transportation data because of a lack of specific air travel data. These extensions are not entirely valid. Nevertheless, in the absence of more appropriate information these data provide an indication of conditions in the Canadian market.

Definition of Air Travel

The product of air passenger transportation is the service supplied in moving people from one place to another at the time the movement is required. Air transportation, as a service, is consumed while it is being produced. Since the product cannot be stored to await future demand, production in excess of demand is lost.

Conversely, demand in excess of available capacity will not await future supply, but will be diverted to surface transportation. These features demonstrate the importance of market research if waste and inefficiency are to be avoided.

Market Demand and Motivation to Travel

The demand for air transportation is a derived demand. The service air transport provides is not valued for itself. Passengers require a journey to a destination, they do not want a ride in an airplane. This may not be strictly true, given that for most people, flying is yet a novelty and constant innovations in aircraft sustain interest. In addition the in-flight and on-the-ground service offered by the airlines is aimed at making the trip itself a pleasant experience, encouraging subsequent trips and enticing passengers off competitive flights. But generally the demand for air travel is a derived demand.

People have different motivations to travel. The literature provides a rough but consistent framework for the reasons why people travel. It appears that a large majority of people travel for one or more of the following reasons:

1. Business, including government and official
2. Private, personal or family reasons
3. Pleasure or tourism.

Personal travel is different from pleasure travel since the former frequently has a compulsion as to date or place which the latter does not. Attending a funeral, a wedding or an anniversary are examples of personal travel. Because private journeys are generally of an infrequent nature, personal and pleasure travel are often grouped together under a non-business category.

Demand in these categories is determined by different factors. The business air travel market is influenced by increased manufacturing and commercial activity coupled with increased trade. More travel is undertaken in search and support of a greater volume of business. The non-business demand is largely dependent upon the income of the traveller.

Several studies have been done on the relative composition of the total travel market with respect to the demand categories. A study by American Airlines (A Profile of the Air Traveller, 1963) found that 50% of American air travelers were on business, 35% were on pleasure journeys, and the remaining 15% were travelling for non-leisure personal reasons. In "The Travel Market" surveys,[1] the Survey Research Centre in Michigan obtained the purpose of interurban air travel over a series of years. The results provide an opportunity to

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[1]John B. Lansing, and others, The Travel Market, (Ann Arbor, Michigan: Survey Research Centre, University of Michigan, 1963).

observe the changes in the proportion of business and non-business travellers for the years 1955 and 1962:

TABLE 1

PERCENTAGE OF AMERICAN AIR TRIPS BY PURPOSE

	1955	1962
Business	63	61
Non-business	37	39

Source: B. J. Elle, Issues and Prospects in Interurban Air Travel, (Stockholm: Almquist & Wiksell, 1968) Table 2:6, p. 31.

Most studies have found business travel to account for between 50 and 70% of air travel. Such a high proportion of business travel suggests that the level and growth of business activity is an important influence on demand.

Characteristics of Air Travellers

The question of "Who travels?" is examined in this section. A small proportion of the total population is responsible for most of the travelling.

TABLE 2

TRAVEL EXPERIENCE OF THE AMERICAN ADULT POPULATION

1962

Number of Trips over 100 miles	% of Adult Population	% of Trips
0	34	0
1-2	28	9
3-4	13	10
5-9	12	17
10-19	8	22
20 or more	5	42
	100	100

Source: B. J. Elle, Issues and Prospects in Interurban Air Transport, (Stockholm: Almquist & Wiksell, 1968) Table 2:3, p. 29.

The table shows that in the United States 34% of the adult population did not make any trips of more than 100 miles in 1962, while 5% accounted for 42% of the travelling and 25% of the adult population accounted for 81% of the travelling.

Relatively few people are responsible for most of the travelling. The next step is to examine the socio-economic composition of the travelling population. The relationship between various socio-economic variables and expenditure on travel may be examined using consumer

expenditure surveys. Such a survey is the Urban Family Expenditure (UFE) survey compiled by Canada's Dominion Bureau of Statistics. This survey is a cross-sectional analysis of the expenditures by a sample number (3000) of families in the eleven major Canadian cities.

Statistics cannot adequately describe the air traveller. Nevertheless, when used with care they can provide an indication of the type of individuals likely to travel. Certain categories of income, age, occupation, and eduction are found to be associated with above average expenditure on travel.

Income

The relationship between income and expenditure on travel may be described in terms of income elasticity. There are two types of elasticity. One type describes the relationship between income and travel for a cross-section of the population at a certain time. This type of income elasticity is derived from consumer expenditure surveys. Surveys in Sweden and the United States[2] have found that at higher income levels families devote a higher proportion of their total expenditure on transportation. The UFE survey shows that a similar relationship appears to exist in Canada.

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[2] Elle, Interurban Air Travel, p. 29, John B. Lansing and others, The Travel Market, (Ann Arbor, Michigan: Survey Research Centre, The University of Michigan, 1963) p. 117.

TABLE 3

PATTERN OF FAMILY EXPENDITURE BY INCOME

ELEVEN CITIES 1964

Income Class	Average Family Expenditure on Transportation	Transportation as a % of total Expenditure	Average Family Expenditure on Air Travel
All Classes	776	12.1	23.00
Under $2500	88	4.5	4.40
2500-2999	301	9.7	29.50
3000-3499	254	6.9	1.40
3500-3999	460	11.2	17.10
4000-4499	441	9.7	12.20
4500-4999	511	10.2	16.10
5000-5499	630	11.3	10.40
5500-5999	829	13.7	17.80
6000-6999	797	12.2	9.70
7000-7999	1098	14.2	17.20
8000-9999	1201	13.9	49.30
10000 +	1578	12.5	57.40

Source: Dominion Bureau of Statistics, Urban Family Expenditures, 1964, Ottawa, Canada: Queen's Printer, 1968.

Although the figures are not entirely consistent, a pattern does seem evident. At higher income levels, families devote a higher proportion of their total income to transportation. Families with incomes above $5500 allocate an above average proportion of their total budget to trans-

portation. The association between income and transportation expenditure is particularly strong. Not only did families with incomes over $5500 spend more than the average on travel, but they devoted a larger than average percentage of their total budget to travel.

For the income variable the UFE survey has expenditure broken down into detailed expenditure categories, one of which is air travel. This relationship is presented in the third column of TABLE 3. In spite of the inconsistencies it appears that a threshhold income level for above average air travel expenditure is $8000.

Most of the above applies more readily to non-business travel. Business travel is normally paid for at the company level rather than by the individual and hence would seem to be independent of the income of the individual. However people with an income above a certain level are more likely to be found in an occupational category which uses air travel as a business service. Moreover it is to be expected that the frequency of business trips increases with increasing levels of income.[3]

The second type of income elasticity describes the relationship between travel expenditures for a certain

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[3] Elle, Interurban Air Transport, p. 27

social group and its changing economic level. The UFE survey is a cross-sectional analysis. Comparing two sets of cross-sectional data, taken in different time periods, gives an indication of changing expenditure patterns. Comparing the 1964 UFE survey with its predecessor in 1959, it is found that while total expenditure increased 20%, expenditure on transportation increased 30%. While transportation as a category increased 30%, it may be expected that the market will appreciate air transportation more rapidly, for the reason that air travel accounts for a growing proportion of total inter-city travel, as is evident in the table below.

TABLE 4

INTERURBAN PASSENGER TRAVEL: CANADA

EACH MODE AS A PER CENT OF TOTAL INTER URBAN PASSENGER-MILES

Year	Automobile	Bus	Air	Rail	Total
1958	84.8	3.8	4.6	6.8	100.0
1959	85.0	3.7	5.1	6.2	100.0
1960	85.5	3.6	5.5	5.4	100.0
1961	86.0	3.4	6.1	4.4	100.0
1962	86.0	3.3	6.2	4.4	100.0
1963	86.4	3.3	6.1	4.2	100.0
1964	85.2	3.3	6.3	5.2	100.0
1965	84.8	3.3	6.9	5.0	100.0
1966	83.8	3.6	7.9	4.6	100.0
1967	81.8	3.7	9.2	5.3	100.0

Source: Dominion Bureau of Statistics, Transportation Service Bulletin, Issue 1, Catalogue Number 50-001, November 1969.

A high average income increases the proportion of "discretionary income" - that portion of income left over after the essentials are covered. Comparing the 1964 UFE survey to the one in 1959 it is found that the essentials, food, clothing, shelter and home furnishings, all showed declining importance in the family budget. The greatest increases are found in the discretionary spending and the most noteworthy item is transportation, which increased from 11.3 to 12.1% of the family budget. Pleasure or personal travel come out of a population's discretionary income. The higher the average income, the greater the proportion of discretionary income.

It is also to be expected that business travel increases as the average income level increases. Increasing incomes denote increasing levels of economic activity which promotes business travel. "The Travel Market" survey by the University of Michigan found the income elasticity for air travel to be 3.0 for business trips and 1.5 for non-business travel.[4]

Age

The UFE survey provides an indication of the relationship between age and travel expenditure. For the age variable a breakdown into detailed expenditure categories, one of which is air travel is provided.

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[4] Ibid., p. 28.

TABLE 5

AVERAGE EXPENDITURE ON AIR TRAVEL BY AGE OF FAMILY HEAD

ELEVEN CITIES 1964

	Average Expenditure per family
All classes	23.00
under 25	37.90
25-34	16.30
35-44	22.40
45-54	33.40
55-59	27.80
60-64	30.10
65-69	7.90
70-74	15.40
75 +	10.00

Source: Dominion Bureau of Statistics, Urban Family Expenditure 1964, Ottawa, Canada: Queen's Printer, 1968.

Again the data is inconsistent but a fairly conclusive trend appears. As age exceeds 64, expenditure for air travel declines. Unfortunately the youngest age category is "under 25", which does not permit one to determine at what age demand falls off at the younger end of the scale. The 1963 Census of Transportation in the United States found that 70% of all travelling was by people in the 18-64 age range. It seems reasonable to conclude that from the entire population, the 18-64 segment is the most influential in determining demand for air travel. For the Canadian urban population in 1966 the 20-64 segment accounts for 38% of the

total population.

Occupation

For the occupational factor the UFE survey provides expenditures only for the broader category of "Transportation other than private automobile".

TABLE 6

PATTERNS OF FAMILY EXPENDITURE BY OCCUPATION OF HEAD

ELEVEN CITIES 1964

	Average Expenditure per Family on Transportation other than Private Automobile
All classes	$130
Managerial	234
Professional and Technical	174
Sales	144
Clerical	136
Craftsman	128
Laborer	107
Services and Recreation	106
Transportation and Communication	85
Not working	78

Source: Dominion Bureau of Statistics, Urban Family Expenditure 1964, Ottawa, Canada: Queen's Printer, 1968.

Clearly the occupational composition of the population will affect the demand for travel. Those occupations experiencing above average expenditure on travel are: managerial, professional and technical, sales and clerical.

Education

An indication of the relationship between education and disposition to travel is given by the UFE survey. Again expenditure is available only for the broader category of "Transportation other than private automobile".

TABLE 7

PATTERNS OF FAMILY EXPENDITURE BY EDUCATION OF HEAD

	Average Expenditure per Family on Transportation other than Private Automobile
All classes	$130
No education	63
Primary partial	93
Primary complete	120
Secondary partial	134
Secondary complete	130
University partial	168
University complete	208

Source: Dominion Bureau of Statistics, Urban Family Expenditure 1964, Ottawa, Canada: Queen's Printer, 1968.

It is clear that higher levels of education are associated with higher levels of expenditure on travel. It appears that those persons above a partial secondary education level have above average expenditure on travel.

Using various demographic variables, a segment of the population with above average expenditure on travel can be separated from the entire population. Some of the characteristics of the "travelling" segment of the

population are that they are between 18 and 64 years of age, have incomes greater than $5500 (or $8000 for air travel), are found in the managerial, professional and technical, sales and clerical occupational categories, and are educated above the secondary-partial level.

Factors Affecting the Amount of Travel

It is difficult to isolate the influence of any one factor on the amount of air travel because so many factors act on demand simultaneously. However, the factors affecting the demand for air travel may be divided into two broad categories: primary and secondary.[6]

The primary factors are population and distance. The relationship between population and air travel is basic. Air travel by definition is the movement of individuals from one place to another. One of the factors influencing the amount of air travel is therefore the number of people involved. The amount of air travel between two centres depends on the total number of possible pairs of individuals who might have occasion to interact, and the probability of any pair actually interacting via air travel. The number of possible pairs is the product of the two populations. The actual volume of air travel is expected to be proportional to this product. Aside from representing the total possible pairs of people

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[6] D'Arcy Harvey, "Airline Passenger Traffic Pattern Within the United States," Journal of Air Law and Commerce, Vol. XVIII, (Spring, 1956) pp. 157-165.

another reason for using population product rather than sum, is that the product reflects the relative size of both cities.

Once established that population is a factor influencing air travel and that the proper measure of the influence of population on air travel is the product of the two populations involved, the question arises as to what definition and measure of population should be used. The entire population of the city constitutes, at least theoretically, potential air passengers. But the entire population does not use air travel. As shown earlier, a small proportion of the population accounts for a large proportion of the travelling. Therefore various attempts have been made to identify "effective" population rather than total population. The "effective" population may be thought of as that part of the total population which are most likely to use air travel services. Using a measure of effective population more accurately identifies potential air travellers.

Income was found to be an important influence on air travel expenditure. Some measure of population which includes only those people with the ability to pay would appear to be appropriate.

Distance between centres is the second primary factor. Distance represents a resistence to the movement of people. It is logical to expect that people who live

far apart will personally interact less frequently than people who live close together. Not only does the cost of travelling in time, effort and money increase with increasing distance, but the likelihood that people will know each other or of an opportunity to justify travel decreases with increasing distance. But the relationship is not quite this simple. The effect of distance on air travel is in fact a composite effect of two general influences. The first which was referred to above is the greater tendency on the part of travellers to make trips where the distance is short. The second is the greater tendency for travellers to prefer air travel when the distance is longer.[7]

If distance is accepted as the second primary factor affecting the amount of air travel, the exact measure of distance must next be examined. Measures of distance that have been suggested in previous studies are time, cost and mileage. Time would appear to be an appropriate measure since total travel time reflects the service standards that the airline has set on the particular route. It was originally intended to use travel time in this study but on close examination certain problems arose. Firstly, centres are often connected by several flights, which differ widely in travel time. For example, from Vancouver to Toronto the travel times range

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[7] Samuel B. Richmond, "Forecasting Air Passenger Traffic by Multiple Regression Analysis," Journal of Air Law and Commerce, Vol. XXII (1955), p. 439.

from 4 hours 5 minutes non-stop, to 6 hours 30 minutes, with three stops. It has been suggested that the shortest travel time should be used. However, there is no ready way of determining the proportion of travellers carried by this "fastest flight". Secondly, direction influences travel time. For example, flying DC 9 non-stop from Toronto to Vancouver requires approximately 4 hours 45 minutes. An eastbound flight with the assistance of more favorable winds makes the trip in an average 4 hours and 5 minutes.

Cost and mileage may be expected to be linearly related and therefore the coice of either is equally valid. Cost has the disadvantage of varying over the 1961-1966 period. Mileage is a more constant measure.

Secondary factors affecting the amount of air travel include the general level of economic activity, management factors and competitive conditions.

One measure of the general level of economic activity is the average income of the population. It is expected that business travel increases as the average income of a population increases. Increasing income levels denote increasing levels of economic activity which promotes business travel. Also, as indicated earlier, a high average income increases the proportion of discretionary income from which personal air travel expenditure is drawn.

Management factors include scheduling, equipment, service standards and promotion. These factors are often very difficult to quantify and as such their effect is possibly better studied as affecting the amount of air travel at the margin. After the expected levels of traffic have been determined using the primary factors, the secondary factors may be more appropriately studied as explaining the variances from expected levels of traffic.

Competitive conditions are another important secondary factor. For example, particularly good rail connections, as between Toronto and Montreal, may divert some traffic from air to rail causing a deviation from the expected rate. As with other secondary factors competition is better studied as a cause of divergence from expected rates of air traffic.

A complete theory of air travel demand should include all of the factors mentioned in this chapter. This would be a formidable task, since most of the secondary factors are difficult to quantify and measure. It has been suggested that a simplified theory using only a few variables will have wide general applicability and will serve as a useful basis for further elaboration. The variables suggested are population and distance, the primary factors. These variables have been expressed in the form of the PP/D hypothesis. The following chapter

reviews the studies which have developed and used the PP/D hypothesis in the analysis of air travel demand.

CHAPTER III

DEVELOPMENT OF THE PP/D HYPOTHESIS APPLIED TO AIR TRAVEL

One of the earliest applications of the PP/D hypothesis to air travel was by G. K. Zipf of Harvard University. Zipf hypothesized that the interchange of goods and people "between any two communities whose respective populations are P1 and P2 and which are separated by the shortest transportation distance D, will be proportionate to the ratio P1 P2/D, subject to the effect of modifying factors."[1]

To test this hypothesis, Zipf plotted the weight of Railway Express that is interchanged between 13 arbitrarily selected cities (78 city-pairs) and their respective values of P1P2/D. Zipf concluded that the relationship was linear and the PP/D hypothesis was valid for the movement of Railway Express between cities. In further study, Zipf found that the circulation of newspapers and the amount of intercity telephone calls also were distributed according to the hypothesis.

Turning to the intercity movement of persons Zipf examined data on passenger traffic by highways, railways and airways for the period 1933-1934. The movement of persons by highway bus travel and railway travel between 29

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[1]G. K. Zipf, "The P1P2/D Hypothesis: On the Intercity Movement of Persons", American Sociological Review, Vol. XII (1947), p. 677.

arbitrary cities was found to be linearly related to corresponding values of P1P2/D. The movement of persons by airway was presented "rather for completeness than for decisive information."[2] In 1933 air travel was just beginning, "yet in spite of the marked variation in the distribution of points there is an unmistakable positive correlation between the number of passengers carried, and their corresponding values of PP/D."[3]

Further testing of Zipf's hypothesis was undertaken by J. A. Cavanaugh[4] in 1948. Cavanaugh compared the actual number of cars entering national parks from a certain state to the number expected according to the PP/D hypothesis. He repeated the analysis for shipments of household goods by moving van companies, postal money orders, university attendence, long distance telephone calls and airline passenger traffic. For airline passenger traffic the coefficient of correlation between expected and observed interaction was 0.58.

S. C. Dodd, in an article, "The Interactance Hypothesis: A Gravity Model Fitting Physical Masses and Human Groups"[5] began with the basic PP/D hypothesis

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[2]Ibid., p. 685.

[3]Ibid., p. 685.

[4]Joseph A. Cavanaugh,"Formulation, Analysis and Testing of the Interactance Hypothesis," American Sociological Review, Vol. XV, Number 6, 1950, pp. 763-766.

[5]Stuart C. Dodd,"The Interactance Hypothesis: A Gravity Model Fitting Physical Masses and Human Groups", American Sociological Review, Vol. XV, (April, 1950) pp. 245-256.

and then introduced variables into the basic formula by making them multiples of the basic variables. Dodd's presentation of the hypothesis appeared as follows:

$$Ie = \frac{k\ IaPa\ IbPb\ T}{L^x}$$

where Ie = expected number of interactions
L^x = the distance between two groups, where the exponent x weights the base factor
Pa = population of group a
Ia = indices reflecting per capita activity, constants which characterize each group
T = time of interacting

The I factors are "weighting factors introduced to equate the heterogeneity of the groups."[6] The I factor may reflect such common influences as differential sex, age, income, education or occupation. If the total population of both groups is homogeneous, then the I factors are unity and hence need not be included in the formula. Similarly if the analysis is of one time period the T factor is one and need not be included. Thus the formula is reduced to

$$Ie = PaPb/L^x.$$

Referring to distance Dodd suggested that distance is most often measured in physical units of miles but that a higher predictance might result from using travel time or travel cost. He further stated that while the

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[6] Ibid., p. 247.

first power of the distance is used in most studies, other exponents may fit the data better.

In an article titled "Airline Passenger Traffic in the United States",[7] D'Arcy Harvey in 1951 examined the factors which determined the airline passenger pattern in the United States. Harvey states that: "The traffic between community x and any other city, with economic character and area density held constant, will be roughly proportionate to the product of the populations of the communities divided by the distance between them."[8] Harvey contends that the economic character of a community influences the traffic generated by that community. To classify this influence, Harvey suggests that communities fall into one of four categories.

> "Marketing centres were defined as lower than average in number employed in mining and manufacturing and higher than average in wholesale sales. Institutional places were lower than average in both number employed in mining and manufacturing and in wholesale sales. Balanced cities were practically average in both number employed in mining and manufacturing and wholesale sales. Industrial cities were higher than average in number employed in mining and manufacturing and lower than average in wholesale sales."[9]

Harvey found that the marketing and institutional centres generated more traffic than balanced cities and industrial centres were lowest in air traffic generation.

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[7]D'Arcy Harvey, "Airline Passenger Traffic within the United States," Journal of Air Law and Commerce, Vol. XVIII, (Spring, 1951), pp. 157-165.

[8]Ibid., p. 162.

[9]G. Roger Mayhill, "A Critique of the C.A.A. Studies on Air Traffic Generation in the United States", Journal of Air Law and Commerce, Vol. XX (1953) p. 163.

The density of communities within a geographic area was another factor mentioned by Harvey as influencing the amount of traffic between any two communities. Harvey explained that: "Where many cities are within an area, the traffic between any pair is minimum because the traffic for each community in the pair is distributed among many. On the other hand where cities are few in an area, the traffic between a pair is maximum as the traffic for each community in the pair is concentrated with the other."[10]

Harvey used the PP/D formula to develop traffic ratios which he then ranked in order of decreasing size of the traffic they exchanged with Chicago. When these rankings were compared to the actual traffic observed, a very close approximation was achieved. The traffic ratios show that Chicago exchanges passengers with 11 other cities in accordance with the PP/D formula, concluded Harvey.

In "A Critique of the C.A.A. Studies on Air Traffic Generation in the United States"[11] G. R. Mayhill examines the validity and reliability of the PP/D hypothesis. Mayhill states at the outset that no rational basis was given in Harvey's work for the PP/D hypothesis other

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[10] Harvey, "Airline Passenger Traffic within the United States", p. 161.

[11] Mayhill, "A Critique of the C.A.A. Studies on Air Traffic Generation in the United States," pp. 158-177.

than the pragmatic justification that it seemed to apply to traffic between Chicago and eleven "balanced" cities. Examining the concept of economic characteristics of cities, Mayhill questions the four classifications, suggesting that marketing and industrial cities might well be combined but separate categories established for gateway, resort, governmental and transportation cities. Mayhill raises the question of whether the population of the entire suburban area or that of the central city should be used as a measure of the size of the community. He suggests that some measure of income (purchasing power) should be included. Modification of the distance factor was considered. For the cities studied travel time did not seem as important as travel cost and direct service. Finally Mayhill criticized the selectivity exercised in the choice of cities, the exemption of some cities and the figures used. Mayhill concludes that the PP/D formula "contains some basic merit but does not cover all cases."[12] Mayhill suggests that the answer to this might be that it fits potential and not actual traffic.

In 1958 S. B. Richmond in an article entitled "Forecasting Air Passenger Traffic By Multiple Regression Analysis"[13] proposed forecasting air traffic by multiple regression analysis. Richmond describes "a technique

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[12] Ibid., p. 175.

[13] Samuel B. Richmond, "Forecasting Air Passenger Traffic by Multiple Regression Analysis", Journal of Air Law and Commerce, Vol. XXII (1955) pp. 434-443.

for forecasting the air passenger traffic that may be expected to travel between two communities in the event that: 1) new airline service in instituted between those two points, or 2) if there is already some type of airline service between the two points, the quality of the service is changed."[14] The analysis involved traffic between Denver and 65 communities with which Denver had air service on a single-plane basis. (i.e. a change of planes was not required)

The analysis proceeded as follows:

> 1. The number of passengers flying between Denver and other cities was analysed and related to other factors such as community of interest with Denver, distance from Denver and quality of the air service offered.
>
> 2. Since data for these other factors could be obtained or hypothecated (as in the case of quality of service) for all cities whether or not they had service with Denver, it was possible, by assuming the same relationship among these factors for the unserved cities as among the served cities, to estimate the air passenger traffic potential between Denver and all other communities.[15]

Many different measures of community of interest were studied:

...population, distance from Denver, air passengers with Denver, hotel registrants at Denver hotels, air freight to and from Denver, surface letter mail, number of home offices of firms with branches in Denver, number of branch offices of firms whose home offices were in Denver, business travel characteristics as compiled from questionnaires sent to Denver business firms, rail passengers with Denver, number of persons renting cars at the Denver airport, number of correspondent banks of

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[14] Ibid., p. 434.

[15] Ibid., p. 436

Denver banks, number of patients admitted to Denver hospitals, number of students at Denver colleges, circulation figures of newspapers and magazines published in Denver, number of charge accounts customers at Denver stores, and the familiar and commonly used community of interest measure, population divided by distance.[16]

From all these measures of community of interest the number of hotel registrants from outside cities was chosen, mainly because the data had specifically collected for the purpose and preliminary graphical analysis had indicated a definite relationship between air passengers and hotel registrants.

The second variable in the multiple regression analysis was the quality of service. The quality of air service it was assumed influenced the amount of air traffic. However, there is a circularity of reasoning involved. An airline may be expected to offer a balanced pattern of service up to the level which it feels the traffic can support. The question of whether service influences traffic or traffic determines service is more properly thought of as a question of interrelatedness. Nevertheless Richmond chose the number of en route stops as a measure of the quality of air service provided.

The third factor considered was distance. Since hotel registrants data was used in the analysis, distance was implicitly considered by its influence on the number of hotel registrants.

The multiple correlation analysis therefore involved

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[16]Ibid., p. 437

three variables: air passengers, hotel registrants and type of service. Richmond concluded that air passengers increase with increasing hotel registrants and decrease with lower levels of service. "The multiple correlation coefficient was found to be 0.91. The significance of this coefficient was tested by the method of analysis of variance, and it was found to be significant."[17]

Daniel M. Belmont[18] states that a complete theory of interurban air traffic should include such factors as population, income levels, characteristic economic activity, travel cost in time and money, special economic bonds, level of service and economic conditions. However, on many routes interstation traffic depends primarily on the product of the total traffic of the terminal stations (which represents the "effective" size of the centre) and the cost factor which he states can be represented by distance. Such routes he calls normal. Normal routes cover a wide range of traffic and distance. Belmont restricts his study to these normal routes, suggesting that abnormal routes are those on which traffic is strongly influenced by special factors and are best studied as deviations from the normal pattern.

It was found that on long distance (more than 800

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[17] Ibid., p. 440.

[18] Daniel M. Belmont, "A Study of Airline Interstation Traffic", Journal of Air Law and Commerce, Vol. XXV (Summer, 1958), pp. 361-368.

miles) non-stop routes, interurban traffic tended to be independent of distance. But when the analysis was extended to cover medium-distance routes (400-800 miles) distance was found to be a significant factor.

When the data was converted to logarithmic form, the correlation coefficient between actual traffic and the PP/D formula for traffic between the 25 largest U.S. cities was .962. What is remarkable, Belmont concluded, is that the formula yields such accurate estimates in view of the great range of traffic and distance, the substantial differences in the quality of service, the existence of special economic ties on some routes and the inevitable random fluctuations.

The economic and social characteristics of a city's population as a factor influencing interurban air travel has been referred to earlier. Wesley H. Long deals with this factor in his article "City Characteristics and the Demand for Air Travel".[19] Long begins his analysis with the basic PP/D hypothesis but notes that different people in a city have different potentials for air travel according to the social and economic characteristics. Thus he states it seems reasonable to give people who have more than one characteristic that is related to air travel more weight

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[19] Wesley H. Long, "City Characteristics and the Demand for Interurban Air Travel", Land Economics, Vol. XLIV (May, 1968), pp. 197-204.

than others by including a number of these variables in an expanded form of the basic PP/D formula. To illustrate, Long suggests instead of using the basic PP/D relationship, that it be expanded to include the influence of income (Y) and education (E) as follows:

$$T_{12} = k \frac{P_1 P_2}{D_{12}} + k_2 \frac{Y_1 Y_2}{D_{12}} + k_3 \frac{E_1 E_2}{D_{12}}$$

Long arbitrarily selects income, education and occupation as factors influencing air travel. The income variable is the ratio of the proportion of people with incomes of $10,000 and over. Education is defined as the number of people with one or more years of college education. Occupation was defined as the number of people employed in companies which employ 100 or more people in that locality. Occupation was defined as "size of business" to avoid correlation with income and education.

Long points out that city pairs do not exist in isolation but in a space occupied by other cities which provide alternative attractions. In considering traffic between two cities A and B, any city which lies at least as close to B as A does would seem to be an alternative. He therefore suggests the inclusion in the model of a ratio of the population of B to the population of the cities in the circle around A with a radius of the distance between A and B. The greater this ratio, the

greater the number of opportunities in city B relative to the area around A and the greater the expected air traffic between A and B.

The results showed that population is the dominant explanatory city characteristic. The location of alternative cities and the size of the business residing in them are factors of secondary importance.

In "An Analysis of Interurban Air Travel",[18] John B. Lansing, Jung-Chao Liu, and Daniel B. Suits examined the principle factors influencing air travel between two cities. They first undertook a preliminary analysis in which a number of variables such as wholesale trade per capita and bank deposits per capita were examined in an effort to distinguish the economic role of the cities. They proved valueless. Only variables measuring distance, population and per cent of families with incomes over $10,000 were retained. This latter variable was used in acknowledgement of the fact that a high proportion of air travel is undertaken for business reasons: "The most frequent users of air transportation are business executives and other persons whose role in the economy is the co-ordination of activities, or more generally, communication from one part of the economy to another."[21] They go on to point out that while occupation-

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[20] John B. Lansing, Jung-Chow Liu, and Daniel B. Suits, "An Analysis of Interurban Air Travel", Quarterly Journal of Economics, Vol. LXXV (February, 1961), pp. 87-95.

[21] Ibid., p. 87

al classifications are too crude to identify such people, they are concentrated in the higher income brackets. Therefore, they continue, it is a reasonable approximation to use the proportion of families with incomes over $10,000 to attempt to identify this segment of the population. They point out that this segment of the population includes those people most likely to purchase air transportation as a consumer service.

The final analysis included 151 cities. In order to hold as many variables constant as possible, they limited the analysis to trips to and from a fixed city. Two studies were made involving New York and Chicago as fixed cities. The number of trips to and from New York (Chicago) and 150 other cities were related by multiple regression analysis to population, distance, and per cent of families with income over $10,000. The regressions were found to be linear in the logarithms of the variables.

The results were inconclusive. "The equality of the income and populations coefficients in the Chicago regression is consistent with the theory that air travel should depend on the number of high income families, whereas travel to and from New York appears to be affected by the whole population rather than by the upper income group alone."[22]

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[22]*Ibid.*, p. 91.

They concluded "that the volume of air travel between two cities varies directly with their populations and the per cent of the population with incomes over $10,000, inversely with the distance between them, and that it is also influenced by other factors peculiar to the cities involved."[23]

In an unpublished Ph.D. dissertation titled "An Evaluation of the Use of Gravitational Formula for Extimating Potential Air Passenger Traffic Between City-Pairs,"[24] D. L. Cochran examined the basic PP/D hypothesis. Into this basic formula he substituted various "sociological measures" and allowed the distance exponent to vary. The aim was to select the combination of "sociological measures" and distance exponent that would yield the highest correlation between expected and actual air passenger traffic.

Cochran restricted his analysis to 11 western states. From these states he selected the 7 largest traffic "hubs", and paired them with the cities listed as exchanging air passengers with the selected "hub" cities. The analysis covered a total of 52 city-pairs.

For "sociological measures", Cochran selected

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[23]*Ibid.*, p. 94.

[24]Douglas L. Cochran, "On Evaluation of the Use of Gravitational Formula for Estimating Potential Air Passenger Traffic Between City-Pairs", Unpublished Ph.D. dissertation Dept. of Business Administration, University of Oregon , 1968.

total population, number of family units with incomes above $10,000 per year, the number of male persons classified as manager, officials and proprietors, the number of installed telephone handsets and the number of passengers departing from the local airport for all destinations. Each variable was separately substituted into the PP/D formula. The number of passengers departing from the local airport for all destinations yielded the highest correlation coefficient of .882.

For a measure of distance Cochran used air miles, and the exponent of distance was allowed to vary between .5 and 2.5. The optimum distance exponent varied from .5 to 1.5 depending on which sociological measure was used. For the total number of passengers departing from local airports for all destinations, the optimum exponent was found to be in the neighbourhood of 1.5. Cochran concluded that the PP/D hypothesis for predicting air passenger traffic "appears to be at least sufficiently accurate to warrant their present use and further development as a management evaluation and control device."

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[25] *Ibid.*, p. 113.

CHAPTER IV

METHODOLOGY

Introduction

The object of this study is to relate air travel demand to factors that cause air travel. While many variables affect traffic growth it is generally impossible to include a large number of variables in one equation. As a first step it is logical to include those factors thought to be the most important. Thus it can be hypothesized that air travel depends primarily on population and distance. Once the basic framework is established, refinements can be introduced to further increase the accuracy of prediction. Certain refinements are introduced in this study to compare their effect to the basic hypothesis using population.

So far, this study has examined the relationships between various factors and air travel demand. This chapter involves an attempt to use some of these relationships to explain air travel demand in Canada. It is useful to study such relationships in the hope that the relationships found can be used to assist in estimating air travel demand. A common technique for approaching such problems is regression analysis. Since there is

only one explanatory variable and the relationship is hypothesized as being linear, this analysis employs simple linear regression analysis, specifically the method of least squares. This method has been programmed for computer solution.

The two time periods under consideration are 1961 and 1966. These years were selected because, both being census years, data was immediately available. The regressions were calculated using annual data. Before the regressions however, population figures were rounded off to millions and total departures and families with incomes greater than $5000 were each rounded off to thousands for easier handling.

Selection of Cities

There are 109 scheduled airline points in Canada as listed in the Air Transport Board publication, Airline Origin and Destination Statistics. Testing air passenger traffic between each point would be pointless because the recorded passenger traffic between many of them is minimal and subject to random fluctuations. As is explained later in this chapter, the basic data on air traffic movement are computed from a sample of every tenth ticket on heavy routes and every fifth ticket on lighter routes. The statistical error in analysis of very small numbers of passenger trips probably would be significant.

Accordingly it was necessary to establish some

criteria for the selection of cities. This was accomplished by selecting the 10 largest traffic generating centres. The largest centres were selected because their traffic is likely to be more stable. Too many random forces can influence a small traffic flow. Larger flows should be much more stable and conforming to the hypothesized PP/D relationship, if indeed this relationship is valid. The centres selected were:

Toronto/Hamilton
Montreal
Vancouver
Edmonton
Winnipeg
Calgary
Ottawa
Halifax
Quebec
Regina

These ten cities, which yield 45 individual routes, vary sufficiently in size (roughly from 100,000 to 2,6000,000) and are sufficiently scattered throughout Canada to constitute a fair sample.

Basic Traffic Data

Airline traffic data used in this study were obtained from "Airline Passenger Origin and Destination Statistics - Domestic Report", a publication of the Air Transport Board available from 1960 to 1967. The survey is confined to mainline (regular service with aircraft in the DC3 class or larger) traffic within Canada. The survey is a continuing (that is throughout the year)

ticket sample covering 10% of the passengers on high volume routes and 20% on the remainder. To avoid duplication airlines are asked to report first issue tickets only.

The traffic figures are compiled on the basis of one-way, single-direction journeys. Round trips are therefore broken into two journeys. Stop-overs or multiple-destination journeys are not considered. For example, a trip from Montreal to Vancouver may involve several visits along the way, but only the initial origin and the final destination are taken into account.

Regarding the accuracy of the figures, the Air Transport Board states that while it is possible that minor errors remain, the data have been subjected to various tests of reliability and are considered to be reasonably accurate. The statistics, of course, will necessarily contain a certain margin of sampling error.

Selection of Explanatory Variables

A major problem in this analysis is to find some explanatory variable(s) which might indicate what the present potential air travel demand is and what future demand is likely to be. The selection of variables, against which to regress observed air travel demand must of course be a simplification, and to some extent arbitrary. Required is a variable which is logically related and highly correlated with air travel demand,

easily and reliably measured, readily available for present and future time periods, and preferably one which is a constant measure, unaffected by such factors as the changing value of money.

This study tests the following variables:

Population

Population satisfies all of the above criteria. Population has been found in past studies to be a reasonably accurate explanatory variable. It is readily available for present time periods, and reasonably reliable forecasts are available.

The population figures used in this study were obtained from the Canada Year Book 1967. Cities are defined as standard metropolitan areas in accordance with census definitions. The population figures are therefore metropolitan populations.

Population, as an explanatory variable, suffers two shortcomings: it does not represent effective air travel population, and it does not reflect the influence of the general level of economic activity on air travel. The following two variables represent attempts to cope with these shortcomings.

Total Airport Departures for all Destinations

This measure was first suggested by Belmont as a measure of "effective" population. He suggests that the measure more accurately reflects the area served by the

airport in question. Also as an actual count of people who have flown from the airport, each individual counted represents, in fact, a potential air traveller. Total population figures it could be argued include people who are not, in reality, potential air travellers. Such a measure is however less readily available for future time periods, in fact, there is a two year lag on its publication for present periods.

Information on total departures was obtained from the Air Transport Board publication Airline Origin and Destination Statistics.

Number of Families with Incomes Greater than $10,000($5000)

This measure has been used by several authors as a more appropriate measure of potential air travellers on an "ability to pay" basis. This variable reflects not only those families who are able to afford air travel as a consumer service but are also those people who are most likely to be in an occupational category and of an educational level who are observed to be above average in expenditure on air travel. The variability of the measure however, reduces its desirability. Incomes are affected by the changing value of money. Part of the addition to the $10,000 and above category could be due to the reduced value of money and does not represent an increased purchasing ability of the family. A more serious shortcoming however is the reduced availability of such a measure.

Taxation Statistics, the source of such data, are typically two years behind and attempts to forecast the size of income categories are infrequent.

The levels of $10,000 and $5000 were selected because they are the only two levels which can be compared consistently for the two time periods. Most of the previous studies used the $10,000 + category. This study used $5000 + because preliminary analysis showed this category to be more closely correlated to air traffic demands.

The source of the data for incomes is the Department of National Revenue publication Taxation Statistics. This report contains an analysis of income tax returns by cities for income classes.

Average Income

Since a high proportion of air travel is undertaken for business reasons it is desirable to test some measure of basic economic activity. Such a measure is the average income of taxpayers in a particular city. Presumably a city with above average income would experience above average business activity and hence would experience above average business air travel demand. This measure was expressed as a ratio of the average income of a particular city to the average income of the 10 major cities used in the study. The ratio was introduced into the equation as a multiplicative factor of

population, representing in effect a weighted population.

Average income figures were obtained from Taxation Statistics and represent average income of taxable and non-taxable returns in each city.

Distance

Distance is the common factor to be used with each of the above variables. The distance factor is to be measured in terms of mileage. As explained above, mileage as a measure of distance is constant and as such will not be a varying influence on the regression coefficients over time. Since it is hoped to find fairly stable regression coefficients so that future forecasts are valid, it is desireable to exclude any changes in the regression coefficients due to changes in the distance factor. The measure of distance to be used is the direct airline distance between cities. This information was obtained from the Atlas of Canada published by the department of Mines and Technical Surveys, Geographical Branch in Ottawa. Rather than presuppose the exact influence of distance the influence of distance was varied by taking various exponents of distance.

The data representing the variables used in the regression analysis are included in the Appendix.

Regression Analysis - Methodology

It is hypothesized that air travel demand between major Canadian cities depends on the population of the

cities and the distance between them. To test this hypothesis, air travel between the 10 major cities (45 city-pairs) was examined for both 1961 and 1966 to ascertain whether the hypothesis was valid and whether the regression coefficients changed over time. For comparison other variables such as the number of tax returns with income greater than $5000 and the total airline departures for all destinations were examined to determine whether the basic population figure could be improved upon.

It is hypothesized that air travel between Canadian cities depends on the population of the two cities and the distance between them. The functional relationship is expressed as follows:

$$T_{12} = f\ (P_{12}\ D_{12})$$

where T_{12} = air travel between city 1 and 2
f = some functional relationship
P_{12} = product of the populations of city 1 and 2
D_{12} = distance between city 1 and 2

The functional form was hypothesized to be linear. The equation appears as follows:

$$T_{12} = A + B\ (P_1\ P_2\ /\ D^x_{12})$$

The formula, when used in regression analysis, develops the average or typical relationship between air travel and computed values of the PP/D formula. It is

then possible, using the resulting equation, to determine expected values of air travel on specific routes based on the average relationship existing on a sample of routes. If the expected values of traffic are then compared with actual traffic, some routes will be over and some will be under. It is then possible to concentrate on the variances to determine what is causing the proper or improper development. In order to determine the stability of the equation over time, regressions were repeated for 1961 population data.

CHAPTER V

ANALYSIS

Regression analysis is the statistical technique employed in this study. Separate regressions were computed using the common factor of distance and data for population, population weighted by average income, total airline departures, and the number of families with incomes greater than $5000.

Population

The primary focus of this paper is on the ability of population and distance to predict air travel. The exponent of distance was varied to achieve the best fitting equation. The results using different exponents of distance are given below:

Exponent of Distance	Resulting R^2
2	.095
1	.585
1/2	.783
1/3	.803
1/4	.802

The relationship between traffic and computed values of $PP/D^{1/3}$ yielded the highest R^2. However, for reasons that will be explained later, $PP/D^{1/2}$ was

selected as the more appropriate relationship. The actual equation for this relationship appeared as follows:

$$T = 13687 + \underset{(.094)}{1.170} \; (PP/D^{1/2})$$

The correlation coefficient, R, was .885 indicating a strong linear relationship. The coefficient of determination, R^2, was .783, indicating that 78% of the variation in traffic over the various routes was explained by the variation in population and distance (population alone yielded a coefficient of .585).

The standard error of the B coefficient was .094, resulting in a calculated student's t distribution value of 12.455. For 43 degrees of freedom at the 5% probability level, the critical t value is 2.021. Therefore the hypothesis that the B coefficient was 0, implying that air travel and computed values of $PP/D^{1/2}$ are not related can be rejected.

The intercept term in this equation was 13,687. Ninety-five per cent confidence intervals for the intercept require a range of approximately 20,000. It can be said with 95% certainty that the intercept term lies somewhere between 2,500 and 25,000.

A useful measure of the accuracy of prediction is provided by the standard error of the estimate. The standard error of the estimate for the equation using 1/2

as the distance exponent was 34,573, almost one-half the size of the standard error of the estimate for the equation using 1/3 as the distance exponent. This is the reason the $PP/D^{1/2}$ relationship was chosen in spite of the slightly (.03) lower R^2.

An error of 34,500 is excessive and raises doubts about the validity of the $PP/D^{1/2}$ hypothesis as a predictive tool. More will be said of this later in the chapter. The study now continues with the analysis of the various substitutes for population.

Population Weighted by Average Income

All populations are not homogeneous in respect to their demand for air travel. One of the factors differentiating populations is the level of economic or business activity carried on by the population. The average income of the population is a measure of basic economic activity. Population weighted by average income is meant to reflect the condition that populations have differing propensities for air travel which are related to their different levels of business activity.

The results of the regressions, as the distance exponent was varied appear as follows:

Exponent of Distance	R^2
1	.560
1/2	.795
1/3	.821
1/4	.822

The relationship PaPa/$D^{1/4}$ yielded the highest R^2 and the lowest standard error of estimate. The actual equation was:

$$T = 6935 + \underset{(.019)}{.262} \, (PaPa/D^{1/4})$$

The t values was 14.08, large enough to reject the hypothesis that B=0. Confidence intervals for the intercept term require a range of from -3000 to 17000. The standard error of the estimate was 31,625.

Number of Families with an Income Greater than $5000 per Year

In recognition of the income/air travel relationship observed in Chapter II, population size should be corrected to the size of the income class $5000 + as a measure of those actually able to purchase air travel. The UFE survey shows that families with incomes greater than $8000 experience above average expenditure on air travel. Unfortunately, Taxation Statistics do not permit a consistent comparison over the years for the $8000 + category. Taxation Statistics are however consistent for the category of $5000 +.

Again regressions were calculated with the distance exponent allowed to vary. The results are summarized below:

Exponent of Distance	R^2
1	.723
1/2	.855
1/3	.857
1/4	.847

The regression equation using the relationship $YY/D^{1/3}$ yielded the highest R^2. This equation was of the form:

$$T = 9062 + \underset{(1.280)}{20.54} \, (YY/D^{1/3})$$

The t value, at 16.04, was sufficiently large to reject the hypothesis that B=0. Ninety-five per cent confidence intervals for the intercept term require a range of approximately 18,000, from 0 to 18,000. The standard error of the estimate was 28,030.

Total Airline Departures for all Destinations

One measure of the traffic generating potential of any city is the actual air travellers departing the city for all destinations. As an actual count of air travellers it is reasoned to be a more accurate representation of the air travelling population of a city.

As in previous cases the distance exponent was varied:

Exponent of Distance	R^2
1	.550
1/2	.822
1/3	.818
1/4	.785

The distance exponent of 1/2 yielded the maximum R^2 and the equation:

$$T = -7968 + \underset{(1.469)}{20.696} \, (AA/D^{1/2})$$

The t values, at 14.08 was large enough to reject the hypothesis that B=0. Ninety-five per cent confidence intervals require a range of approximately 12,000, from 2000 to 14,000. The standard error of the estimate was 31,265.

Returning now to the problem of the high standard error of the estimate, it will be recalled that the aim of the study was to develop a reliable predictive equation. The standard error of the estimate provides a useful measure of the accuracy of prediction. If the population equation referred to above is used for predictive purposes, a probability statement with 95% confidence would require a range of approximately 70,000. Clearly a range of 70,000, when only 5 of the 45 routes examined are larger than 70,000, is excessive. This condition raises serious doubts about the utility of the PP/D hypothesis in predicting air traffic. Moreover, when this condition was further examined, increased doubts about the general validity of the PP/D hypothesis were raised, as is now explained.

An analysis of the residuals between expected and actual traffic showed that the largest residuals were associated with the smallest distance. Therefore it was believed that the exclusion of the shorter routes would improve the overall regression. The original data were divided into three categories: short distance routes were those less than 400 miles, medium distance routes ranged from 400 to 1000 miles, and long distance routes

were over 1000 miles. Separate regressions were computed for each of these categories.

The short distance routes, of which there are 7, appear to be independent of distance. Population product alone yielded an R^2 of .877 with a standard error of 59904. Including distance, to any exponent, reduced the R^2 and increased the standard error of estimate.

There were 14 medium distance routes. Again distance appeared to be irrelevant. Even population alone was a very poor predictor with an R^2 of .365 and a standard error of estimate of 23881.

Only for long distance routes did the inclusion of distance improve the results over population alone. Population alone yielded an R^2 of .671 and a standard error of 12,481. Population with distance to the exponent of 1/2 yielded an R^2 of .702 and a standard error of 11,877. Even though the standard error here appears to be small relative to previous cases it must be remembered that the traffic flow over longer routes is itself much smaller.

The results must be looked upon as disappointing in terms of the validity and general applicability of the PP/D hypothesis. The second part of the hypothesis was that the relationship between observed air travel and calculated values of PP/D was stable over time. To test this hypothesis the regression using population and

distance with the exponent of 1/2 was rerun with 1961 data. The results together with those for 1966 appear below:

$$1966 \qquad T = 13678 + \underset{(.094)}{1.170}\,(PP/D^{1/2})$$

$$1961 \qquad T = 5068 + \underset{(.079)}{1.184}\,(PP/D^{1/2})$$

While the equations are not coincident, they do appear to be nearly parallel. The coefficient of determination for the 1961 (1966) data was .839 (.783).

CHAPTER VI

CONCLUSION

Summary

The object of this study was to relate air travel demand to the primary factors influencing air travel. The primary factors were assumed to be population and distance. These factors were expressed in the functional form:

$$T = f\ (PP/D^{x})$$

Various substitutes for population were tested and compared. Basic population was only slightly improved upon. The distance exponent was varied to achieve the most appropriate equation. In all cases distance raised to the power of less than 1 provided more appropriate results. In spite of the reasonably high coefficients of determination (.8), practical application of the relationship was limited by the size of the standard error of the estimate.

When the original data were divided into three categories based on distance (short, medium and long distance routes) empirical evidence did not consistently support the PP/D hypothesis. Short and medium distance routes were found to be independent of distance.

Limitations of the Study

A complete theory of air travel demand should include all factors influencing traffic. However it is possible to begin with an approximate theory which uses only a few of the more important variables. Such a beginning will serve a useful basis for further elaboration. The application of an approximate theory requires a knowledge of the limitations of the formula as well as a more fundamental understanding of the complexity of air transportation and its markets. In this study the formula is limited to two of the many factors discussed in Chapter II, and as such is a simplification of a more complex situation.

The fact that over 50% of air travel is undertaken for business purposes suggests that business activity must be explicitly recognized in the theory. Perhaps a greater recognition of the influence of business activity on air travel demand is called for.

In evaluating the results of the regression analysis, the basic limitations of this statistical technique must be considered. One such limitation is the fact that one is attempting to explain the behavior of complex phenomena with only two variables. Secondly regression analysis provides no proof that the dependent variable is causally related to the independent variable. The theory of causality must be established through the inclusion of logically related independent variables. Regression

analysis then indicates whether the hypothesized relationship is consistent with historical facts.

Conclusion

The purpose of the study was to determine whether air travel between major Canadian cities can be explained and predicted by two factors, population and distance, the relationship between which is hypothesized to be of the form PP/D. It is concluded that the PP/D hypothesis cannot be used to predict air travel demand between Canadian cities. Especially significant is the finding that short and medium distance routes appear to be independent of distance. This is especially significant because the bulk of air travel in Canada takes place over short distances. The average length of flight for Air Canada's domestic system in 1965 was 327 miles.

The hypothesis set further at the beginning of this study of a linear relationship must be questioned. The size of the correlation coefficient, and the acceptance of the equations based on the t test of significance would appear to support the hypothesis. But the existence of the large standard error of the estimate and the improved results brought about by exponential values of distance could seem to indicate a curvilinear relationship. Further study in this area might begin with a logarithmic transformation of the data.

However, the shortcoming of the approach may be

even more basic. Broad theories covering a wide range of cities may not be the most useful approach. The Canadian air travel market may not yet be sufficiently developed to achieve the stability observed in the studies of the American market. The Canadian situation may yet require that each route be examined individually.

The airlines themselves do not attempt to apply broad theories. Perhaps this is significant. They point out that it is very difficult to measure traffic on specific routes, they are content to measure traffic on blocks of routes, such as from the prairies to the maritimes. For individual route estimates, they use extrapolation of time series data.

On the whole the validity of the PP/D hypothesis has not been confimed in this study. Rather indications are that the hypothesis has been refuted at least for short and medium distance routes. Individual route analysis may yet be the most practical method of analysis, until eventually a more complete picture of the air traffic pattern in Canada can be drawn.

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DISSERTATIONS

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APPENDIX

TABLE 1

REGRESSION DATA 1966

	Population	Number of Tax Returns with incomes greater than $5000.	Average Income	Total Departure from local airport
Calgary	331,000	56,000	5507	191,000
Edmonton	401,000	63,000	5176	217,000
Halifax	198,000	16,000	4935	122,000
Montreal	2,437,000	311,000	5446	504,000
Ottawa	495,000	65,000	5753	175,000
Quebec	413,000	43,000	5088	84,000
Regina	131,000	21,000	5163	70,000
Toronto/Hamilton	2,608,000	473,000	5592	685,000
Vancouver	892,000	139,000	5609	381,000
Winnipeg	509,000	73,000	4969	195,000

TABLE 2

TRAFFIC ON ROUTES BETWEEN 42 CITY-PAIRS (T) AND CORRESPONDING PRODUCTS OF POPULATION (P), POPULATION WEIGHTED BY AVERAGE INCOME (Pa), DISTANCE (D), NUMBER OF TAX RETURNS WITH INCOME GREATER THAN $5000 (Y), AND TOTAL DEPARTURES FROM LOCAL AIRPORTS FOR ALL DESTINATIONS (A)

1966

City-Pair	T	P	Pa	D	Y	A
Calgary-Edmonton	125825	132731	135192	170	3528	41447
-Halifax	1950	65538	63296	2642	896	23302
-Montreal	18315	806647	863440	2097	17416	96264
-Ottawa	7865	163845	185760	2012	3640	33425
-Quebec	660	136703	136224	2252	2408	16044
-Regina	27885	43361	43668	480	1176	13370
-Tor/Ham	44895	863248	941872	1768	26488	130835
-Vancouver	75930	295252	321984	475	7784	72771
-Winnipeg	27555	168479	164432	806	4088	37245
Edmonton-Halifax	1730	79398	72398	2588	1008	26474
-Montreal	15095	977237	986430	2043	19593	109368
-Ottawa	9470	198495	212220	1958	4095	37975
-Quebec	690	165613	155628	2198	2709	18228
-Regina	13570	52531	49911	471	1323	15190
-Tor/Ham	38755	1085808	1076034	1714	29799	148645
-Vancouver	71535	357692	367848	645	8757	82677
-Winnipeg	24990	204109	187854	752	4599	42315
Halifax-Montreal	52795	482526	461840	545	4976	61488
-Ottawa	15810	98010	99360	630	1040	21350
-Quebec	2625	81774	72864	482	688	10248
-Regina	810	25938	23368	2162	336	8540
-Tor/Ham	54125	516384	503792	874	7568	83570
-Vancouver	3695	176616	172224	3117	2224	46482

-Winnipeg	3525	100782	87952	1836	1168	23790
Montreal-Ottawa	30595	1206315	1355400	85	20215	88200
-Quebec	81925	1006481	993960	155	13373	42336
-Regina	5985	319247	318770	1617	6531	35280
-Tor/Ham	458875	6355696	6872380	329	147103	345240
-Vancouver	41165	2173804	2349360	2572	43229	192024
-Winnipeg	37040	1240433	1199780	1291	22703	98280
Ottawa-Quebec	12170	204435	213840	240	2795	14700
-Regina	4650	64845	68580	1532	1365	12250
-Tor/Ham	168820	1290960	1478520	244	30745	119875
-Vancouver	14735	441540	505440	2487	9035	66675
-Winnipeg	20020	251955	258120	1206	4745	34125
Quebec -Regina	270	54103	50292	1772	903	5880
-Tor/Ham	24005	1077104	1084248	484	20339	57540
-Vancouver	1480	368396	370656	2727	5977	32004
-Winnipeg	1255	210217	189288	1446	3139	16380
Regina -Tor/Ham	19820	341648	347726	1288	9933	47950
-Vancouver	14160	116852	118872	955	2919	26670
-Winnipeg	29525	66679	60706	326	1533	13650
Tor/Ham-Vancouver	87150	2326336	2562768	2243	65747	260985
-Winnipeg	95880	1327472	1308764	962	34529	133575
Vancouver-Winnipeg	47295	189104	447408	1281	10147	74295

TABLE 3

TRAFFIC ON ROUTES BETWEEN 42 CITY-PAIRS (T)
AND CORRESPONDING PRODUCTS OF
POPULATION (P) AND DISTANCE (D)

1961

City-Pair	T	P	D
Calgary-Edmonton	59140	94302	170
-Halifax	1590	51336	2642
-Montreal	8600	588690	2097
-Ottawa	4060	119970	2012
-Quebec	370	99882	2252
-Regina	15440	31248	480
-Tor/Hamilton	28400	619390	1768
-Vancouver	57320	220410	475
-Winnipeg	17975	132804	806
Edmonton-Halifax	1220	62192	2588
-Montreal	10055	713180	2043
-Ottawa	5765	145340	1958
-Quebec	410	121004	2198
-Regina	10270	37856	471
-Tor/Ham	23440	750360	1714
-Vancouver	54400	267020	645
-Winnipeg	18125	160888	752
Halifax-Montreal	37130	388240	545
-Ottawa	9665	79120	630
-Quebec	1760	65872	482
-Regina	520	20608	2162
-Tor/Ham	33045	408840	874

-Vancouver	2160	145360	3117
-Winnipeg	2330	87584	1836
Montreal-Ottawa	30275	907300	85
-Quebec	69515	755380	155
-Regina	3110	236320	1617
-Tor/Ham	338170	4684200	329
-Vancouver	23105	1666900	2572
-Winnipeg	24355	1004360	1291
Ottawa -Quebec	7305	153940	240
-Regina	2640	48160	1532
-Tor/Ham	122055	954600	244
-Vancouver	8950	339700	2487
-Winnipeg	9890	204680	1206
Quebec -Regina	90	40096	1772
-Tor/Ham	18345	794760	484
-Vancouver	530	282820	2727
-Winnipeg	1150	170408	1446
Regina -Tor/Ham	12875	248640	1288
-Vancouver	10155	88480	955
-Winnipeg	20010	53312	326
Tor/Ham-Vancouver	48545	1753800	2243
-Winnipeg	70435	1056720	962
Vancouver-Winnipeg	31680	376040	1281

TABLE 4

ANALYSIS OF RESIDUALS

$T = f\ (PP/\sqrt{D})$

Expected	Actual	Difference
25589	125825	100235
15170	1950	-13220
34288	18315	-15973
17952	7865	-10087
17049	660	-16389
15994	27885	11891
37699	44895	7195
29529	75930	46401
20622	27555	6933
15504	1730	-13774
38975	15095	-23880
18927	9470	-9457
17811	690	-17121
16510	13570	-2940
43234	38755	-4479
30157	71535	41378
22387	24990	2603
37862	52795	14933
18247	15810	-2437
18036	2625	-15411
14331	810	-13521
34115	54125	20010
17380	3695	-13685
16430	3625	-12905
166768	30595	-136173
23136	81925	58788
22967	5985	-16982
423657	458875	36218
63820	41165	-22655
17600	37040	19440
29118	12170	-16948
15617	4650	-10967
110385	168820	58444
24038	14735	-9303
22167	20020	-2147
15182	270	-14912

70962	24055	-46907
21932	1480	-20452
20146	1255	-18891
24817	19820	-4997
18102	14160	-3943
17999	29525	11526
71150	87150	16000
63755	95880	32125
19860	47297	27436